

Technology for carrying out hydraulic fracturing using a new material ‘nitinol’

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Abstract. The paper examines the causes of proppant backflow from a fracture to a well, and presents the main technologies for proppant control. The consequences of the removal of the fracture filler into the wellbore are determined. It has been noted that proppant backflow is most damaging to wells operated by electric centrifugal pumps. Existing methods of hydraulic fracturing are investigated, their disadvantages are indicated. A method has been developed for hydraulic fracturing with injection of compressed springs made of metal with the effect of ‘memory’ and restoring their shape under reservoir temperature stress. In the first stage, the remote section of the crack is filled with a fine fraction of ceramic proppant, and at the final stage of crack attachment, compressed springs made of nitinol material are fed. Using of material with a shape memory will allow the proppant packing to be compacted and the proppant to be ‘locked’ in the fracture.

1. Introduction

In the process of hydraulic fracturing (fracking) through the action of high pressure on the reservoir, a system of cracks is created into which granular material (proppant) is transported to fix the crack in the open state after relieving the overpressure [1]. Often there is a spontaneous proppant exit from the created hydraulic fracture beyond the reservoir (to water-saturated horizons) and hydraulic fracturing design optimization [2].

It is known that proppant backflow from a fracture into a well occurs after hydraulic fracturing during initial treatment and in some cases even after a well is fully developed [3]. One of the reasons for the removal of granular material from the fracture into the well is the destruction of the filler particles when pressed into the fracture, and the uneven distribution of particles in the fracture [4].

The filling of cracks with proppant is characterised by high permeability, high fluid velocities and the manifestation of inertial forces [5]. It is also noted that the wings of the crack work less efficiently, respectively, and the removal of proppant mainly comes from the central part of the crack. The backflow of proppant from the fracture to the well leads to a decrease in the conductive width of the fracture as a result of a decrease in the wedging effect, up to its complete collapse (Figure 1).

Due to the removal of the fracture filler, potentially high well flow rates are reduced, proppant plugs are formed on the bottom, which requires additional well flushing and the overhaul period of the electric centrifugal pump (ECP) is also reduced.



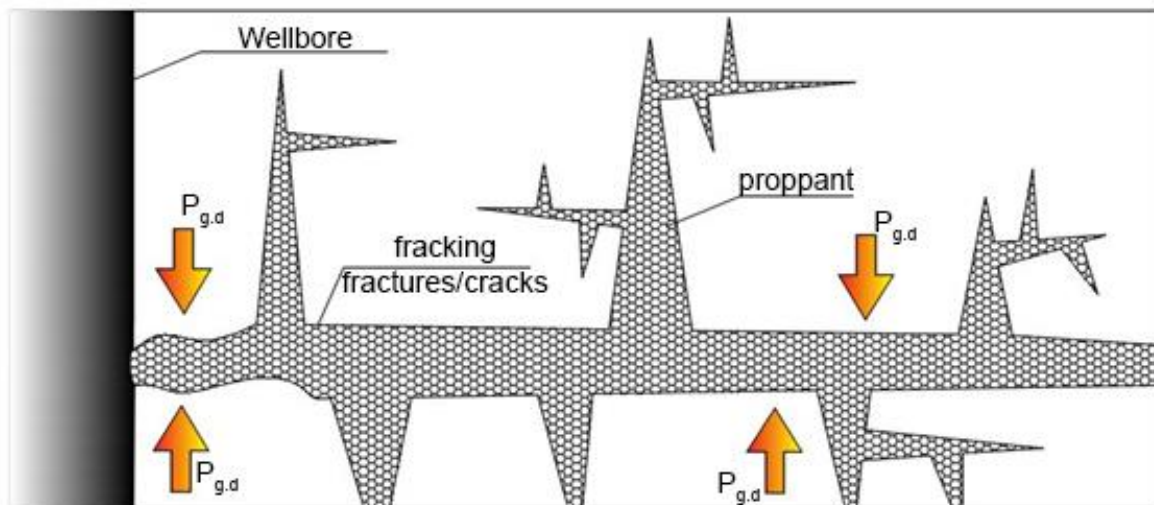


Figure 1. Reduction of the conductive width of the crack.

An analysis of the causes of failure of submersible pumps confirms that proppant back flow (PBF) is most harmful for wells operated by electric centrifugal pumps. ESPs with which a significant part of oil producing wells are equipped in our country are quickly clogged with proppant after hydraulic fracturing and fail ('ESP wedge' occurs) [6]. Because of this, the ESP, which is first installed in the well after hydraulic fracturing, is called a 'sacrificial pump' (Figure 2).



Figure 2. The negative effect of the back flow of the crack filler into the well on an ECP, clogged with proppant, during the working stage.

2. Materials and methods

To solve the problem, methods of hydraulic fracturing were investigated [7–8]. The analysis showed that the problem of fixing and holding the proppant in the fracture has not been solved at the present time. The considered methods have the following disadvantages:

- the use of a proppant, without taking into account the size of the fracture, makes it difficult to keep the proppant particles in the crack;
- there is no reliable filtration layer during the formation of the proppant crack frame;
- the occurrence of various fluids in the well, such as acids, gels and destructors leads to the destruction of the polymer and a decrease in the strength of the proppant itself, with its destruction and the formation of mobile abrasive particles in the stream;

- during transportation of the composite proppant along the axial channel of the drill pipe string, their adhesion inevitably occurs to the inner surface, with the formation of a proppant plug;
- the use of granular material of the same fractional composition to fill a hydraulic fracture along its entire length stimulates the process of particle migration into the well, since at the outlet into the wellbore, the flow rate of the formation fluid sharply and repeatedly increases.

In connection with the presence of an urgent problem, the technology of hydraulic fracturing with the injection of pressed springs from nitinol at the final stage of crack attachment is proposed. Nitinol is an alloy of titanium (45%) and nickel (55%) in the proportion of 45 to 55%, which has high corrosion and erosion resistance. It is unusual that this alloy has a memory effect. If the item is heated to red heat, then it will return this form. After cooling to room temperature, the part can be deformed, but when heated, it will return to its original shape. The response temperature range depends on the chemical composition of the alloy and can be changed depending on the required indicators. The shape of the element can be set in the laboratory using the recommended heat treatments. This behaviour is due to the fact that this material is an intermetallic compound and, when quenching, the mutual arrangement of atoms is ordered, which leads to shape memory. Super elasticity manifests itself during the transition upon heating from one structural internal state to another. Upon reaching the value of phase transformation, the alloy as a spring takes its original form.

3. Results and discussions

The proposed method of hydraulic fracturing includes running of the pipe string with the packer into the wellbore, the overlap of the annulus above the roof of the producing formation, the supply of hydraulic fracturing fluid along the pipe string with the creation of overpressure with a crack fixer, in the form of proppant particles of the calculated fractional composition, holding time. The dimensions of the granules used to fill remote zone of reservoir and near wellbore zone of hydraulic fracture are determined in such a way as to prevent the migration of proppant particles by the flow of reservoir fluid. At the first stage, the remote section of the crack is filled with a fine fraction of ceramic proppant, and at the second stage, a large fraction of particles formed from a metal having a memory effect and changing their shape is supplied, with the formation of a filtration layer in the hydraulic fracture when exposed to formation temperature (figure 3).

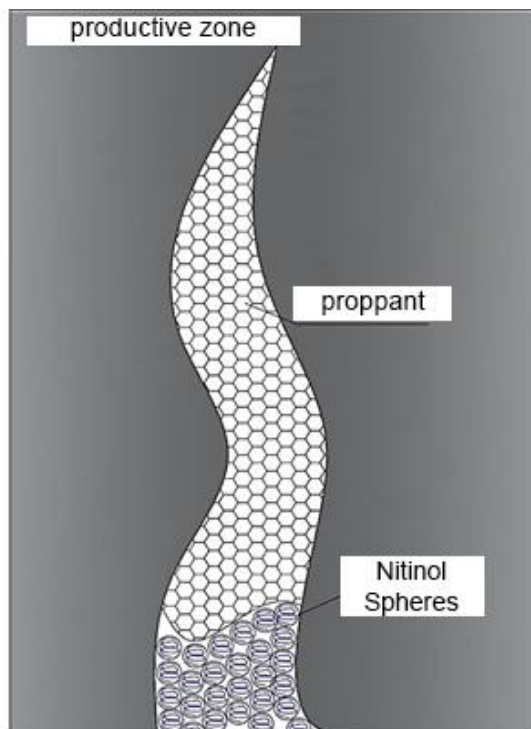
To ensure the fixation of proppant particles in the near – wellbore zone, we determine its diametrical dimensions by the formula:

$$d_{\text{prop}} = \frac{V_{\text{cr}}}{V_{\text{f}}} \cdot d_{\text{p}},$$

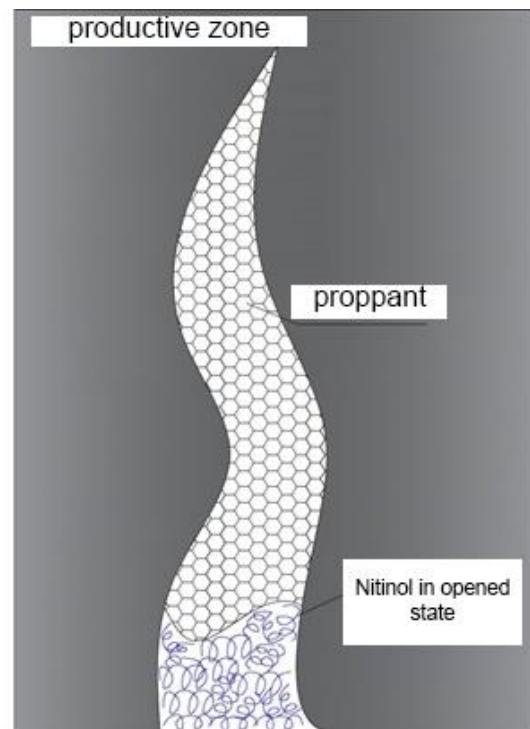
where d_{prop} – is the diameter of the proppant particles at the outlet of the fracture into the wellbore, mm; V_{cr} – formation fluid flow rate at the outlet to the wellbore, m/s; V_{f} – the rate of filtration of the reservoir fluid at a remote section of the fracture, mm/s; d_{p} – the diameter of the proppant particles at a remote section of the fracture, mm.

When the proppant particles are diametrically sized to fill a crack in a remote area within $d_{\text{p}} = 0.2\text{--}0.4$ mm, the grain size in the near-well zone should be $d_{\text{prop}} = 2\text{--}3$ mm.

To ensure the supply of such proppant particles to the fracture, it is necessary to select the composition of the working fluid and the speed of transportation in the interval of the reservoir. Displacement fluid is pumped into the volume of the tubing string, ensuring that the suspension is completely displaced into the fracture. The formation of the filtration layer by springs from nitinol in the borehole zone of the hydraulic fracture is carried out in a chaotic arrangement.



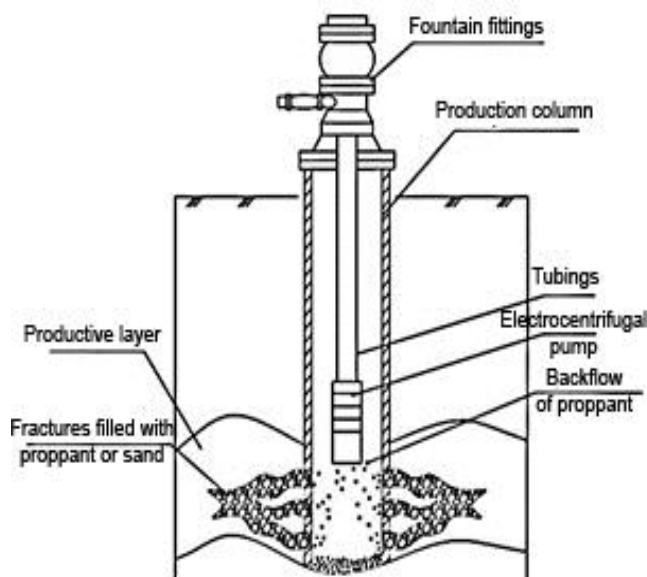
A – proppant granule from the material ‘nitinol’ in the hydraulic fracture in an unopened state



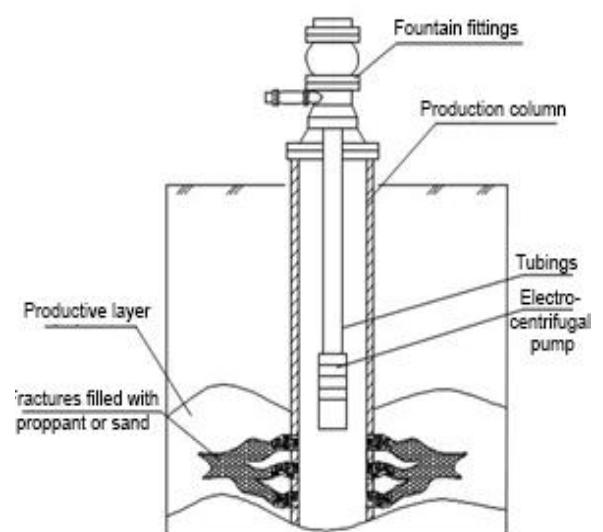
B – proppant from the material ‘nitinol’ in the hydraulic fracture in the open state after exposure to temperature

Figure 3. Using ‘nitinol’ to fix hydraulic fracture of the formation.

The conductivity of such a material can be tested at the developed stand [9]. ‘Nitinol’ has a better holding capacity compared to proppant or sand. Furthermore, the injection of material with shape memory at the final stage of the crack attachment will allow the proppant packing to be compacted and, in turn, to block the proppant in the crack (Figure 4).



Proppant backflow using existing technologies



Lack of proppant back flow when using nitinol

Figure 4. Schematic diagram of the proposed crack attachment technology.

4. Conclusion

The proposed technology for strengthening cracks after hydraulic fracturing received a positive decision on the grant of a patent of the Russian Federation [10].

The application of this method in practice will obtain the following technical results:

- the delivery of proppant particles to the peripheral part of the fracture while maintaining their position in the process of reservoir fluid filtration during well development and hydrocarbon production;
- the formation of a highly permeable screen of the filter layer of the fracture in the near-wellbore zone in the presence of a large proppant fraction with optimal placement of hydraulic fracturing in the fracture;
- the possibility of forming a highly permeable screen in the borehole zone in the form of segments of helical coil springs made of metal having the 'memory' effect and restoring their shape due to the formation temperature.

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